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REVISION I

TO THE USERS' MANUAL FOR THE APOLLO GUIDANCE ANALYSIS STATISTICAL TRIALS PROGRAM

(This document supersedes MSC Internal Note No. 69-FM-53 dated March 3, 1969)

Orbital Mission Analysis Branch

MISSION PLANNING AND ANALYSIS DIVISION

MANNED SPACECRAFT CENTER

HOUSTON, TEXAS

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CHANGE SHEET

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MSC INTERNAL NOTE 69-FM-95 DATED APRIL 25, 1969

REVISION 1

TO THE USERS' MANUAL FOR THE

APPOLLO GUIDANCE ANALYSIS

STATISTICAL TRIALS PROGRAM

By Dennis M. Braley

Change 2

June 23, 1969

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Page 1 of 22
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1. Replaces pages 6, 11, 12, 14, 15, 16, 18, 20, 39, 51, 52, 54, 56 57, and 60.

2. Add pages 11a, 16a, and 16b.

CHANGE SHEET

FOR

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REVISION 1

TO THE USERS' MANUAL FOR THE

APOLLO GUIDANCE ANALYSIS

STATISTICAL TRIALS PROGRAM

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1. Replaces pages 25, 40, 41, 43, 46, 60, 61, 61A, and 62.

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PROJECT APOLLO

REVISION I TO THE USERS' MANUAL FOR THE APOLLO GUIDANCE ANALYSIS STATISTICAL TRIALS PROGRAM

By Dennis M. Braley
Orbital Mission Analysis Branch

April 25, 1969

MISSION PLANNING AND ANALYSIS DIVISION

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

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REVISION I TO THE USERS' MANUAL FOR THE APOLLO GUIDANCE ANALYSIS STATISTICAL TRIALS PROGRAM

By Dennis M. Braley

SUMMARY

This users' manual presents a discussion of the capabilities of the AGAST computer program and the output available from it. Complete instructions are given for preparing input cards to obtain the desired results.

INTRODUCTION

The AGAST program performs Monte Carlo error analyses for Apollo rendezvous missions. AGAST simulates onboard targeting, guidance, and navigation computations. The program models the onboard guidance and navigation systems of the CMC, LM PGNCS, and LM AGS. Also modeled are some of the RTCC rendezvous maneuver targeting computations and MSFN state vector updates. The RTCC maneuver targeting simulated includes the DOI maneuver, the NCC-NSR maneuver sequence, and the DKI maneuvers NC1, NH, and NSR. In performing an error analysis of a mission profile, the program may model any or all of those four computers.

The trajectory error analysis scheme of AGAST is to first produce a nominal, or reference, trajectory; that is, no guidance or navigation errors are introduced into the computations. The program is then cycled to produce several simulations of the mission profile. Each simulation consists of initializing and maintaining an "actual" trajectory and for each monitored computer an "estimated" trajectory. The actual trajectory is initialized as a random dispersion of the initial reference state vector. The estimated trajectories are dispersions of the actual.

The actual state vectors are propagated with an analytic ephemeris predictor which is assumed to be error free. The estimated state vectors are propagated with routines which simulate the onboard integrators. Simulation of a mission plan includes modeling of errors in the onboard systems; i.e., platforms, accelerometers, and tracking devices. Engine thrust profile discrepancies are also considered.

[a]This revision supersedes MSC internal note no. 69-FM-53 dated March 3, 1969.

After the required number of Monte Carlo simulations are produced, the statistical characteristics of the trajectory dispersions and the ΔV required to fly the mission plan are computed. The statistics include means and standard deviations of maneuver ΔV's. Covariance matrices that represent uncertainties in state vectors are also produced.

SYMBOLS

AEG	analytic ephemeris generator
AGAST	Apollo Guidance Analysis Statistical Trials
AGS	abort guidance subsystem
APS	ascent propulsion subsystem
CDH	constant differential height maneuver
CSI	concentric sequence initiation
CSM	command and service module
CMC	command module computer
DKI	docking initiation
DOI	descent orbit insertion
DPS	descent propulsion subsystem
G.m.t.	Greenwich mean time
LV	local vertical
MSFN	Manned Space Flight Network
NC1	DKI phasing maneuver
NCC	corrective combination maneuver
NH	DKI height maneuver
NSR	coelliptic maneuver
PGNCS	primary guidance and navigation control subsystem

RCS	reaction control subsystem
REFSMMAT	rotation matrix from basic reference coordinate system to the IMU platform coordinate system
RR	rendezvous radar
RTCC	Real-Time Computer Complex
SCT	scanning telescope
SOI	stable orbit insertion
SOM	stable orbit midcourse
SOR	stable orbit rendezvous
SPS	service propulsion subsystem
SXT	sextant
TPF	terminal phase finalization
TPI	terminal phase initiation
TPM	terminal phase midcourse
VHF	very high frequency

CURRENT CAPABILITIES

The following list presents the basic current capabilities of AGAST. Detailed descriptions of methods used in AGAST will be documented in a separate internal note.

Potential Model

Either earth or lunar potential models may be used. This capability allows error analyses to be performed for earth rendezvous missions, such as Apollo 9, or for lunar rendezvous missions, such as Apollo Missions F and G. The lunar potential may be varied to study the effects on rendezvous for any proposed potential model.

Computers Monitored

The program user may have the program "monitor" any combination of CMC, PGNCS, AGS, and RTCC computers. To monitor a computer means that AGAST simulates the computations of that computer and maintains estimated state vectors for it.

Trajectory Tracks

Several trajectory tracks are maintained.

1. A reference trajectory is produced.

2. For each Monte Carlo cycle an actual trajectory is computed.

3. For each Monte Carlo cycle an estimated trajectory is computed for each monitored computer.

Trajectory Initialization

Trajectory initialization requires the following:

1. The initial reference state vector, X_R, must be input.

2. The initial actual state vector, X_A, may be set equal to X_R or defined as a dispersion of X_R which is either input or formed from a random sampling of an input covariance matrix.

3. The initial estimated states, X_E, for the monitored computers are either the same as the actual state or some input dispersion from the actual.

Monte Carlo Samples

The program user must define the number of Monte Carlo samples desired. The program may generate up to 100 Monte Carlo samples and may perform statistical processing on 10 different events in the mission plan.

Maneuver Simulation Capability

The user has several options pertaining to maneuver targeting and simulations:

1. Targeting computed, but ΔV not applied to the state vector.

2. ΔV impulsively applied to the state vector (without errors modeled).

3. ΔV burn controlled by onboard guidance equations and systems errors modeled.

The following maneuver options may be used by the program user.

1. Target ΔV: Update the CSM (LM) state in the PGNCS (CMC) by impulsive simulation of a maneuver which has been performed by the CSM (LM)
2. External ΔV guidance
3. SOI
4. SOM
5. SOR
6. CSI
7. CDH
8. TPI
9. TPM
10. Direct intercept
11. Direct transfer to input target
12. TPF (impulsive simulation of braking)
13. NCC
14. NSR
15. Staging
16. Plane change

17. DOI

18. Powered descent to the lunar surface

19. Powered ascent into lunar orbit

20. Powered lunar descent with abort into powered ascent

21. CSM lunar orbit plane change

22. DKI maneuvers NC1 and NSR

23. LM insertion corrective (TWEEK) maneuver

AGAST has AGS capability for ASCENT, CSI, CDH, TPI, TPM, and external ΔV maneuvers.

Targeting Studies

For a given maneuver the program may be commanded to compute targeting based on the estimated states of any or all of the four computers: CMC, PGNCS, AGS, and RTCC. Since the different computers will produce different maneuver times for some maneuvers, the targeting based on the actual states may be computed for each of these different times. That is, AGAST may produce eight targeting solutions for a given maneuver:

1. CMC/CMC - the CMC solution computed at the CMC predicted maneuver time.

2. PGNCS/PGNCS - the PGNCS solution computed at the PGNCS predicted maneuver time.

3. AGS/AGS - the AGS solution computed at the AGS maneuver time.

4. RTCC/RTCC - The RTCC solution computed at the RTCC maneuver time.

5. ACT/CMC - the solution based on the actual state vectors but computed for the CMC predicted maneuver time.

6. ACT/PGNCS - the solution based on the actual state vectors but computed for the PGNCS predicted maneuver time.

7. ACT/AGS - the solution based on the actual state vectors but computed for the AGS predicted maneuver time.

8. ACT/ACT - the solution based on the actual state vectors and computed for the predicted maneuver time also based on the actual state vectors.

Of course, the burn simulation is controlled by the targeting computed for the controlling computer.

Thrust Model

The input or stored thrust model may be changed at any point in the mission plan.

Alinements

Platform alinements are simulated by computing the platform orientation matrix REFSMMAT. Platform errors are reinitialized with each alinement. The REFSMMAT may be computed for the following types of alinement:

1. Nominal alinement

2. Preferred maneuver alinement

3. Lunar surface alinement

The AGS platform may be alined to the PGNCS, and the PGNCS estimated states are put into the AGS.

Updates

The estimated states of one computer may be used to update one of the other computers. This option provides for the planned procedures of voicing update information between vehicles.

Both estimated states in a computer may be updated by sampling an input 12-by-12 or 6-by-6 covariance matrix of MSFN tracking uncertainties.

RR and SXT Updates

RR and SXT updates may occur as follows.

1. An estimated state in the LM PGNCS or the AGS may be updated by sampling an input 6-by-6 covariance matrix that represents RR tracking uncertainties.

2. An estimated state in the CMC may be updated by sampling an input 6-by-6 covariance matrix that represents SXT tracking uncertainties.

3. An estimated state in the LM PGNCS or the AGS may be updated by simulation of the navigational measurements and computations associated with the RR.

4. An estimated state in the CMC may be updated by simulation of the navigational measurements and comuptations associated with the SXT and VHF ranger.

Landmark Tracking

The CSM estimated state may be updated in the CMC by modeling the optical landmark tracking measurements and the associated navigation computations.

Error Sources

The following list presents the sources of discrepancies between reference, actual, and estimated trajectories.

1. Onboard integrators - AGS has a Keplerian model. The PGNCS earth model does not consider atmospheric drag.

2. MSFN tracking uncertainties

3. Platform misalinement and drift

4. Accelerometer misalinement, bias, and scale factor

5. RR noise and bias on range, range rate, and shaft and trunnion angles

6. SXT noise and bias on the line-of-sight unit vector

7. VHF noise and bias on range measurements

8. Randomly perturbed engines thrust profile characteristics

9. Thrust misalinement modeled by computing random burn residuals

Target Differences

For a given maneuver, statistical processing may be performed on the targeting parameter differences that result from the actual state vectors and the estimated states of the four computers. The following ΔV target differences can be formed and statistical characteristics produced.

1. CMC/CMC minus ACT/CMC
2. PGNCS/PGNCS minus ACT/PGNCS
3. AGS/AGS minus ACT/AGS
4. RTCC/RTCC minus ACT/ACT
5. PGNCS/PGNCS minus CMC/CMC
6. PGNCS/PGNCS minus AGS/AGS
7. PGNCS/PGNCS minus RTCC/RTCC
8. RTCC/RTCC minus CMC/CMC
9. RTCC/RTCC minus AGS/AGS
10. CMC/CMC minus AGS/AGS

Use in Onboard Program Verification

If zero samples are run (i.e., NSAM = 0) and any error sources are not considered, AGAST can be used to make runs to verify the results of various programs modeled in AGAST for the CMC, LM PGNCS, and AGS, as defined in references 1 through 6.

OUTPUT

There are two kinds of output from AGAST: (1) checkout and debugging output and (2) output generated by the statistical processor of AGAST. For every event, the program user must define a print control flag which determines the level of output which is printed for every Monte Carlo simulation of that event. For example, if the user requests a maneuver event, he may or may not have the targeting parameters displayed for each guidance cycle of each simulation of that maneuver.

Though the program is not limited in the number of mission events which may be simulated, it can statistically process only ten events. That processing pertains to generation of sample means and standard deviations for the following.

1. The total ΔV required to fly the mission

2. The ΔV burned for the individual maneuvers

3. The ΔV targeting solution for the individual maneuvers produced by the different computers

Also generated for a sampled mission event are sample covariance matrices which represent uncertainties in the CSM and LM state vectors, that is, deviations of the actual from the reference, and of the estimated from the actual. Such sample covariance matrices are computed for the relative state vector for the CSM and LM.

Output for statistical processing is written on magnetic tape after each cycle through the program. If the program should terminate before completion, a special driver exists if the user desires to process cases completed before the termination.

INPUT

The input to AGAST is of two types: (1) initializing input, which will not change for a given mission plan and (2) event input, which defines the mission events to be simulated. The program is initialized by defining the initial reference state vectors for the two vehicles and by defining other initialization paramaters such as the numerical error models to be used. (The initialization input and its card format is defined in the section giving detailed input descriptions as input blocks O and A through H.)

The mission profile to be modeled is defined to the program as a sequence of events. Each mission event is specified to AGAST on a block on input cards called an event package. There are no program restrictions on the number of events which may be specified. There are four major event categories.

1. Maneuvers

2. Alinements

3. Vector transfers (computer-to-computer)

4. Tracking and state vector updates

The event input definitions and format are defined in the detailed input description as input blocks EVENT, LEC1, LEC2, LEC3, and LEC4. The input block denoted EVENT is read for every event, and each event package is headed by the cards of this input block. Block EVENT specifies the several control flags which define the event and the manner in which it is to be simulated. For each event, the program reads input block EVENT, and subsequently one of the four input blocks LEC1, LEC2, LEC3, and LEC4, which correspond respectively to a maneuver, an alinement, a vector replacement (MSFN updates), and onboard tracking. Each input block is divided into sections so that each section is a specific data unit usually contained on a single card. Detailed descriptions of all the input blocks follow.

Prestored Data

The latest available data are maintained as prestored data inside the program. The sources are onboard fixed memory data - references 1 through 5; onboard erasable memory data - MPAD memorandums; error analysis data - reference 11.

Matrix Input Format

(Format MATRIX)

Covariance matrices used in AGAST, whose dimensions are multiples of six, are input by means of the format described below. This format allows the matrix to be input by reading in only the upper triangular elements and also provides a simple method to input the matrices of dimensions greater than six such as those encountered in the two-vehicle MSFN update matrix and the ascent performance matrix. In subsequent pages of this manual, this format is referred to by the name MATRIX.

Because the method used consists of partitioning matrices of dimension greater than six into submatrices each of which is of dimension six by six, consider first a matrix A of dimension six by six.

The elements of A are input by rows, one row to a card, in the format (6F12.0). Thus, the input sequence is as follows.

A(I,J), J = 1, 6), I = 1, 6)

To simplify the input, only the upper triangular values are input whenever possible. In this case, the input sequence is as follows.

A(I,J), J = I, 6), I = 1, 6)

The format used here is the same as the format used to enter the whole matrix as input, but the areas of the card for the lower left elements of the matrix are left blank. For all matrices of dimension six, only the upper triangular values are entered.

For a matrix B of dimension KD where KD is a multiple of six, first partition B into six by six submatrices A_{mn}. Next, with each A_{mn} considered as an element of B, a matrix of dimension JD is formed where JD = KD/6. The input sequence is again by rows, and only the upper triangular values are included, which gives the sequence

$$A(m, n), n = m, JD), M = 1, JD)$$

For the diagonal submatrices of the partitioned matrix (A_{mn} where m = n), only the upper triangular values are entered.

As an example, when KD = 12, B is partitioned as shown.

$$B = \left(\begin{array}{c|c} A_{11} & A_{12} \\ \hline A_{21} & A_{22} \end{array}\right)$$

The input sequence is A_{11}, A_{12}, A_{22} with only the upper triangular values entered as input for matrices A_{11} and A_{22}.

Block 0 Input - Program Initialization Data

The input to block 0 sets the program initialization flags and reads in the initial reference state. When the LM is on the lunar surface, no LM reference state is input.

The base date is the date to which the reference vector is referenced. The vector time should be input as Greenwich mean time (G.m.t.). The time and date are of importance in transformations between the planetary coordinate system (Greenwich true of date or selenographic) and the inertial basic reference system (Besselian or selenocentric). All output state vectors in AGAST are in the basic reference system.

Section	Variables	Format	Cards
0	Comment cards	10A6	2
1	KREF, IORB, IMON(CMC), IMON(PGNCS), IMON(AGS), IMON(RTCC), NSAM, NREF, IPERTA(CSM), IPERTA(LM), IPERTE(CSM), IPERTE(LM), IBRAKE, IDATA, KPROP, JRAN	16I5	1
1b	IBLOCKA, IBLOCKB, IBLOCKC, IBLOCKD, IBLOCKE, IBLOCKF, IBLOCKG, IBLOCKH	8I5	1
2	BYEAR, BMONTH, BDAY	3F10.0	1
3	KORIN(CSM), ISET(CSM), ICON(CSM), ITIME(CSM)	4I5	1
4	VECTOR(CSM)	variable	1 or 2
5	VECTIME(CSM)	variable	1 or 2
6	KORIN(LM), ISET(LM), ICON(LM), ITIME(LM)	4I5	1
7	VECTOR(LM)	variable	1 or 2
8	VECTIME(LM)	variable	1 or 2
9	GMTLØ	4F10.0	1

Section	Variable	Definition
0		Two comment cards containing any information the user wishes to be displayed for this profile
1	KREF	central body designation flag
		= 1 earth orbit
		= 2 lunar orbit
	IORB	LM reference state flag
		= 0 LM reference state is input
		= 1 LM is on lunar surface and no reference state is input in sections 6 through 8
	IMON	computer monitoring flags
		= 0 do not monitor this computer
		= 1 monitor this computer
	NSAM	the number of Monte Carlo samples to be run; the maximum number of samples allowed is 100
	NREF	the number of reference points where a statistical analysis is desired; up to 25 reference points may be selected
	IPERTA	initial actual state control flag
		= 0 actual state equals the input reference state
		= 1 actual state equals the input reference state plus input dispersion
		= 2 actual state equals the input reference state plus dispersion computed from sampling a local vertical actual state covariance matrix
		= 3 the same as for IPERTA = 2 except that the covariance matrix is in UVW coordinates
		= 4 the LM actual and estimated states are computed from the reference state using a 13 by 13 lunar ascent insertion uncertainty matrix; in this case, IPERTE(LM) is ignored, and all monitored computer LM states are set equal
	IPERTE	initial estimated vector control flag
		= 0 estimated state equals the actual state
		= 1 estimated state equals the actual state plus input dispersion

Section	Variable	Definition
	IBRAKE	breaking control flag
		= 0 do not simulate braking
		= 1 simulate braking
	IDATA	data block control flag
		= 0 all data in blocks A through H is set to its prestored value
		= 1 some of the data for blocks A through H will be read into the program
	KPROP	propagation model control flag (lunar orbit only)
		= 0 TRIAX propogation desired
		= 1 R2 propogation desired
	JRAN	random number control flag
		= 0 use the random number generator
		= 1 zero out all random numbers used
1b	This section is included only if IDATA = 1	
	all below	data block control flags
		= 0 all data for the block is taken to be the prestored value
		= 1 all or part of the data is input
	IBLOCKA	state vector propagation model control flag
	IBLOCKB	state vector initial perturbation model control flag
	IBLOCKC	platform error model control flag
	IBLOCKD	thrust profile control flag
	IBLOCKE	rendezvous radar data control flag

Section	Variable	Definition
	IBLOCKF	sextant data control flag
	IBLOCKG	lunar landmark tracking data control flag
	IBLOCKH	lunar ascent and descent data control flag
2	BYEAR, BMONTH, BDAY	base date
3	KORIN	coordinate system flag for the input reference state = 0 the elements are in Greenwich true of date coordinates (earth orbit) or selenographic coordinates (lunar orbit) = 1 the elements are in Besselian coordinates (earth orbit) or selenocentric coordinates (lunar orbit)
	ISET, ICON	flags which define the form of the input reference vector ISET = 1 Keplerian elements (a,e,i,g,h,l) ICON = 1 elements are in units of ft and deg = 2 elements are in units of ft and rad = 3 elements are in units of n. mi. and deg = 4 elements are in units of n. mi. and rad ISET = 2 rectangular elements (X, Y, Z, $\dot{X}$, $\dot{Y}$, $\dot{Z}$) ICON = 1 elements are in units of ft and fps ICON = 2 elements are in units of n. mi. and fps ICON = 3 elements are in canonical units ICON = 4 elements are in units of e.r. and e.r./hr

Section	Variable	Definition

ICON = 5 elements are in units of meters and meters/sec

If a minus is placed on above values of ICON when ISET = 2, then the elements are read in the octal format instead of the decimal format (See section 4)

ICON = 6 RTCC vector package input (see the discussion at the end of this block

ISET = 3 spherical elements (V, γ, Ψ, R, λ, ϕ)

ICON = 1 elements are in units of ft, fps and deg

ICON = 2 elements are in units of ft, fps, and rad

ICON = 3 elements are in units of n. mi., fps and deg

ICON = 4 elements are in units of n. mi., fps and rad

ICON = 5 elements are in units of ft, fps and deg measured geodetically (earth orbit only)

ISET = 4 elements are height of apogee, height of perigee, inclination, argument of perigee, argument of the ascending node, and true anomaly (h_a, h_p, i, g, h, θ)

ICON = 1 elements are in units of ft and deg

ICON = 2 elements are in units of n. mi. and deg

Section	Variable	Definition
	ITIME	vector time control flag
		= 0 the time is in the form days, hr, min, and sec and is on two cards. The first card contains the number of days in the format (F10.0); the second card contains the hr, min, and sec in the format (11X, F4.0, 1X, F3.0, 1X, F5.2)
		= 1 the time is on one card in the form days, hr, min, and sec in the format (4F10.0)
		= 2 the time is on one card in sec in the format (F10.0)
	VECTOR	this section contains the input reference vector elements; if ISET = 2, the format is (10X, 3E15.8) for decimal input and is (11X, 012, 1X, 012, 1X, 012) for the octal input and in either case there are two cards; if ISET = 2, the vector is on one card in the format (6F12.0)
5	VECTIME	the reference vector time in the form and format specified by the ITIME flag of section 3; if ITIME = 0, the time is on two cards

Sections 6 through 8 are included only if IORB = 0

Section	Variable	Definition
6		See section 3
7		See section 4
8		See section 5
9	GMTLO	Lift-off time or any other time from which g.e.t. values are desired in the program output. The time is in the form days, hr, min, and sec

RTCC VECTOR PACKAGE

The RTCC transmits vectors to the RTACF in a seven-card package. Use of the vector package has been included in AGAST for use in real time operations and postflight analysis when the vector package is available.

When the vector package option is used, KORIN must be set to one and ITIME is ignored. When the vector package is used, it replaces sections 4 and 5 (for the CSM) and/or sections 7 and 8 (for the LM). Also, the weights input in block A are ignored.

The contents of the vector package are shown below as a reference for the user.

Card	Description	Format
1	Station ID	12X, A4, 1X, A3, 8X, A1
2	G.m.t. of lift-off	11X, F4.0, 1X, F3.0, 1X, F5.2
3	VECTIME	11X, F4.0, 1X, F3.0, 1X, F5.2
4	Rev number	11X, F3.0
5	Vehicle position	11X, Ø12, 1X, Ø12, 1X, Ø12
6	Vehicle velocity	11X, Ø12, 1X, Ø12, 1X, Ø12
7	Vehicle weight	11X, F6.0

Block A Input - State Vector Propagation Model Data

Block A input is the drag model constants and the initial vehicle weights. At present the initial estimated vehicle weights are set equal to the initial actual weights inside the program.

This block is included only if IBLOCKA = 1.

Section	Variables	Format	Cards
1	CD(CSM), CD(LM), AREA(CSM), AREA(LM), WHT(CSM), WHT(LM)	6F10.0	1

Section	Variable	Definition
1	CD	drag coefficient
	AREA	spacecraft area, ft^2
	WHT	spacecraft weight, lb

Block B Input - State Vector Perturbation Data

Block B allows the user to apply initial perturbations of the actual states from the reference states and of the estimated states from the actuals. When covariance matrices are used for the dispersions, the matrix is sampled each cycle and a new set of dispersions is computed. When dispersions are input, the same dispersions are added each cycle through the program.

Dispersions of the estimated states by covariance matrices are not input through block B. If the user desires such a dispersion it must be input as a vector replacement event (block LEC3).

This block is included only if IBLOCKB = 1.

Section	Variables	Format	Cards
1	DXA(CSM)	6F10.0	1
2	COVA(CSM)	6F10.0	6
3	DXE(CSM, CMC)	6F10.0	1
4	DXE(CSM, PGNCS)	6F10.0	1
5	DXE(CSM, AGS)	6F10.0	1
6	DXE(CSM, RTCC)	6F10.0	1
7	CSA(LM)	6F10.0	1
8	COVA(LM)	MATRIX	6
9	JMFLAG COVLA	4I5 MATRIX	1 variable
10	DXE(LM, CMC)	6F10.0	1
11	DXE(LM, PGNCS)	6F10.0	1
12	DXE (LM, AGS)	6F10.0	1
13	DXE(LM, RTCC)	6F10.0	1

Section	Variable	Definition
1	This section is included only if IPERTA(CSM) = 1	
	DXA	rectangular perturbations in Apollo local vertical coordinates which are used to form the initial actual state from the input reference state
2	This section is included only if IPERTA(CSM) = 2 or 3	
	COVA	6-by-6 covariance matrix from which a random sampling is taken to obtain the perturbations used to form the initial actual state from the input reference state. Each card inputs a row.
3	This section is included only if IPERTE(CSM) = 1 and IMON(CMC) = 1	
	DXE	rectangular perturbation to the CSM state vector in Apollo local vertical coordinates which are used to form the initial CMC estimated state vector from the actual
4	This section is included only if IPERTE(CSM) = 1 and IMON(PGNCS) = 1	
	DXE	See section 3
5	This section is included only if IPERTE(CSM) = 1 and IMON(AGS) = 1	
	DXE	See section 3
6	This section is included only if IPERTE(CSM) = 1 and IMON(RTCC) = 1	
	DXE	See section 3
7	This section is included only if IPERTA(LM) = 1	
	DXA	See section 1
8	This section is included only if IPERTA(LM) = 2 or 3	
	COVA	See section 2

Section	Variable	Definition
9	This section is read only if IPERTA(LM) = 4	
	JMFLAG	flags which designate which sections of the LM ascent performance matrix are to be used. The sections (each a six by six matrix) are as follows 1. CSM estimated state computed from the CSM actual state 2. LM actual state computed from the LM reference state 3. LM PGNCS estimated state computed from the LM actual state 4. LM AGS estimated state computed from the LM actual state The flag values are as follows = 0 do not use this section of the matrix = 1 use this section of the matrix
	COVLA	LM ascent performance matrix which represents uncertainties in the LM actual and estimated states and the CSM estimated state at insertion after a lunar ascent by the LM. The matrix is in UVW coordinates from the LM reference state local vertical. The size of matrix COVLA varies because it is composed of only the sections designated by the JMFLAG values and the cross correlations between those sections.
10	This section is included only if IPERTE(LM) = 1 and IMON(CMC) = 1	
	DXE	See section 3
11	This section is included only if IPERTE(LM) = 1 and IMON(PGNCS) = 1	
	DXE	See section 3
12	This section is included only if IPERTE(LM) = 1 and IMON(AGS) = 1	
	DXE	See section 3
13	This section is included only if IPERTE(LM) = 1 and IMON(RTCC) = 1	
	DXE	See section 3

Block C Input - Platform Data

Platform error models are available for the CMC, LM PGNCS, and LM AGS computers. The AGS platform does not have a REFSMMAT as it is initialized by means of a PGNCS to AGS alinement (block LEC2).

If IBLOCKC = 0, no input is needed for this BLOCK, and IPE will be set to zero by the program.

Section	Variables	Format	Cards
1	IPE, IPLTSG, IREFSMMAT, IPDATA	4I5	1
2	REFSMMAT(CSM)	3E15.8	3
3	ALNERR(CSM)	3E15.8	1
4	DRFTR(CSM)	3E15.8	1
5	ACRER(CSM)	3E15.8	3
6	ABIAS(CSM)	3E15.8	1
7	SKALE(CSM)	3E15.8	1
8	SIGALN(CSM), SIGDFT(CSM), SIGAAL(CSM), SIGABI(CSM), SIGASK(CSM)	5E15.8	1
9	REFSMMAT(LM)	3E15.8	3
10	ALNERR(LM, PGNCS)	3E15.8	1
11	DRFTR(LM, PGNCS)	3E15.8	1
12	ACRER(LM, PGNCS)	3E15.8	3
13	ABIAS(LM, PGNCS)	3E15.8	1
14	SKALE(LM, PGNCS)	3E15.8	1
15	SIGALN(LM, PGNCS), SIGDFT(LM, PGNCS), SIGAAL(LM, PGNCS), SIGABI(LM, PGNCS), SIGASK(LM, PGNCS)	5E15.8	1
16	ALNERR(LM, AGS)	3E15.8	1
17	DRFTR(LM, AGS)	3E15.8	1
18	ACRER(LM, AGS)	3E15.8	3
19	ABIAS(LM, AGS)	3E15.8	1
20	SKALE(LM, AGS)	3E15.8	1
21	SIGALN(LM, AGS), SIGDFT(LM, AGS), SIGAAL(LM, AGS), SIGABI(LM, AGS), SIGASK(LM, AGS)	5E15.8	1

Section	Variable	Definition
1	IPE	platform error flag
		= 0 do not consider platform errors
		= 1 consider platform errors
	IPLTSG	platform error source flag
		= 0 use prestored or input platform errors
		= 1 compute platform errors from σ's
	IREFSMMAT	REFSMMAT control flag
		= 0 use prestored REFSMMAT matrix
		= 1 input the REFSMMAT matrix
	IPDATA	platform data source control flag
		= 0 use prestored errors or σ's
		= 1 read in platform errors or σ's

If IPE = 0 or IPDATA = 0, no further data are included in this block with the possible exception of sections 2 and 9

2 This section is included only if IMON(CMC) = 1 and IREFSMMAT = 1

	REFSMMAT	rotation matrix from the basic reference coordinate system to the IMU platform coordinate system

Sections 3 through 8 are considered only if IMON(CMC) = 1; if IPLTSG = 0, sections 3 through 7 are included; if IPLTSG = 1, then section 8 is included

3	ALNERR	platform misalignment errors for each of the three axes, rad
4	DRFTR	platform drift rates for each axis, rad/sec
5	ACRER	accelerometer misalignment matrix, ft/sec^2

Section	Variable	Definition
6	ABIAS	accelerometer bias for each axis, ft/sec^2
7	SKALE	accelerometer scale factor for each axis
8	SIGALN	misalignment σ, rad
	SIGDFT	drift rate σ, rad/sec
	SIGAAL	accelerometer misalignment σ, ft/sec^2
	SIGABI	accelerometer bias σ, ft/sec^2
	SIGASK	accelerometer scale factor σ
9	This section is included only if IMON(PGNCS) = 1 or IMON(AGS) = 1 and IREFSMMAT = 1	
	REFSMMAT	See section 2
10 - 15	See corresponding section in sections 2 through 8.	
	Sections 16 through 21 are considered only if IMON(AGS) = 1; if IPLTSG = 0, sections 16 through 20 are included; if IPLTSG = 1, then section 21 is included	
16 - 21	See corresponding section in sections 3 through 8	

Block D Input - Thrust Profile

Each of the three engines, the SPS, DPS, and APS, is modeled by means of a thrust profile. Each profile consists of ten possible phases, and each phase is defined by a thrust level, a specific impulse, and a time duration.

The time duration of each phase is specified by the time, in seconds after phase 1 ignition, at which that phase is to end. A phase starts only after the completion of the previous phase. The time of the main engine phase should be input as a large number to allow completion of the burn and main engine phase termination by the guidance.

The tailoff phase must be input as phase 10 and any unused phases between main engine phase and tailoff are left empty. The phase time input for this phase is the time duration of tailoff in seconds.

An option exists in the main engine phase of the profile for each engine to use a thrust level that varies linearly over a specified time. This option is used as follows. The thrust level of the main phase is set to the level desired at the beginning of the variation, and the phase time is set so that the phase ends at the completion of the linear variation. The thrust level of the phase after the main phase is set to the level desired at the end of the linear variation. Because the phase after the main phase essentially becomes the main phase when this option is used, its phase time is set to a large value.

When RCS engines are requested, the program uses the levels for phase 1 of the SPS and DPS for the CSM and LM, respectively. However, in the RCS burns, the program ignores the phase times.

When IBLOCKD = 0, no data is included in this block and the actual thrust profile is set according to the prestored parameters.

Section	Variables	Format	Cards
0	JEFLAG(I), I = 1, 32	16I5	2
1	IME(SPS), IME(DPS), IME(APS), ITHRC(SPS), ITHRC(DPS), ITHRC(APS), ITHROT	7I5	1
2	THR(I, SPS), I = 1, 10	5F10.0	2
3	THR(I, DPS), I = 1, 10	5F10.0	2
4	THR(I, APS), I = 1, 10	5F10.0	2
5	PTHRE(I, SPS), I = 1, 10	5F10.0	2
6	PTHRE(I, DPS), I = 1, 10	5F10.0	2
7	PTHRE(I, APS), I = 1, 10	5F10.0	2
8	SIGTHR(I, SPS), I = 1, 10	5F10.0	2
9	SIGTHR(I, DPS), I = 1, 10	5F10.0	2
10	SIGTHR(I, APS), I = 1, 10	5F10.0	2
11	SPI(I, SPS), I = 1, 10	5F10.0	2
12	SPI(I, DPS), I = 1, 10	5F10.0	2
13	SPI(I, APS), I = 1, 10	5F10.0	2
14	PSPIE(I, SPS), I = 1, 10	5F10.0	2
15	PSPIE(I, DPS), I = 1, 10	5F10.0	2
16	PSPIE(I, APS), I = 1, 10	5F10.0	2
17	SIGSPI(I, SPS), I = 1, 10	5F10.0	2
18	SIGSPI(I, DPS), I = 1, 10	5F10.0	2
19	SIGSPI(I, APS), I = 1, 10	5F10.0	2
20	PHT(I, SPS), I = 1, 10	5F10.0	2
21	PHT(I, DPS), I = 1, 10	5F10.0	2
22	PHT(I, APS), I = 1, 10	5F10.0	2

Section	Variables	Format	Cards
23	ITHR(I, SPS), I = 1, 10	10I5	1
24	ITHR(I, DPS), I = 1, 10	10I5	1
25	ITHR(I, APS), I = 1, 10	10I5	1
26	THRA(I, SPS), I = 1, 10	5F10.0	2
27	THRA(I, DPS), I = 1, 10	5F10.0	2
28	THRA(I, APS), I = 1, 10	5F10.0	2
29	SPIA(I, SPS), I = 1, 10	5F10.0	2
30	SPIA(I, DPS), I = 1, 10	5F10.0	2
31	SPIA(I, APS), I = 1, 10	5F10.0	2
32	ENO, C	2F10.0	1

Section	Variable	Definition
0	JEFLAG	engine data control flags corresponding to sections 1 through 32 of this block and designating whether the corresponding section is read
		= 0 use the prestored values for this section
		= 1 read in this section
1	IME	the number of the phase in the thrust profile that is the main engine phase
	ITHRC	main engine phse thrust control flag
		= 0 main engine phase thrust is constant
		= 1 main engine phase thrust varies linearly
	ITHROT	DPS throttling control
		= 0 normal DPS operation
		= 1 manually throttled maneuver over-riding short burn logic
2-4	THR	nominal thrust levels of each phase of each engine, lb
5-7	PTHRE	thrust percentage error used to compute actual thrust levels from the nominal
8-10	SIGTHR	error σ's used to compute the actual thrust levels from the nominal, lb
11-13	SPI	nominal specific impulse of each phase of each engine, sec
14-16	PSPIE	percentage errors used to compute the actual specific impulse values from the nominal
17-19	SIGSPI	error σ's used to compute the actual specific impulse values from the nominal values, sec

Section	Variables	Definition
20-22	PHT	phase times for each phase of each engine, sec
23-25	ITHR	control flags on each phase of each engine which indicate how the actual thrust and SPI are to be computed from the nominal for this phase = 0 actual equals nominal plus percentage error = 1 actual equals nominal plus a random sampling of the corresponding error σ = 2 actual is input
26-28	THRA	actual thrust level in LB for each phase where ITHR flag equals 2; values for other phases can be omitted from the input card
29-31	SPIA	actual SPI values in sec for each phase where the ITHR flag equals 2; values for all other phases can be omitted from the card
32	ENO	the number of RCS thrusters to be used
	C	steering parameter

Block E Input - RR Data

This block inputs the error model for the rendezvous radar measurements. The input consists of noise and bias values on each of the four quantities measured by the RR (range, range rate, shaft angle, trunnion angle).

If BLOCKE = 0, no data are included in this block.

Section	Variables	Format	Cards
1	IRBIAS, INRRR, INRRA	3I5	1
2	SIGRRB	4E15.8	1
3	RRBIAS	4E15.8	1
4	$SIGRRN_r$, $SIGRRN_{\dot{r}}$	2E15.8	1
5	$SIGRRN_\theta$, $SIGRR_\beta$	2E15.8	1

Section	Variable	Definition
1	IRBIAS	RR bias control flag
		= 0 use pre-stored σ's to compute the biases
		= 1 use read in σ's to compute the biases
		= 2 read in the biases
	INRRR	range and range rate control flag
		= 0 use pre-stored noise σ's for range and range rate
		= 1 use input noise σ's
	INRRA	RR angle control flag
		= 0 use pre-stored angle noise σ's
		= 1 input angle noise σ's
2	This section is read only if IRBIAS = 1	
	SIGRRB	σ's for computing the RR range, range rate, shaft, and trunion biases; in ft, fps, and rad, respectively
3	This section is read only if IRBIAS = 2	
	RRBIAS	biases for RR range, range rate, and shaft and trunion angles; in ft, fps, and rad, respectively
4	This section is read only if INRRR = 1	
	$SIGRRN_r$	σ for range noise, ft
	$SIGRRN_{\dot{r}}$	σ for range rate noise, fps
5	This section is read only if INRRA = 1	
	$SIGRRN_\theta$	σ for shaft angle noise, rad
	$SIGRRN_\beta$	σ for trunion angle noise, rad

Block F Input - Sextant Data

This block inputs the error model for the CSM sextant. The input consists of angle measurement noise and bias values for each of the three axes of the sextant and for the VHF ranger.

If IBLOCKF = 0, then no data are read for this block.

Section	Variable	Format	Cards
1	ISXTB, ISXTN	2I5	1
2	SGSXTB	4E15.8	1
3	SXTBIA	4E15.8	1
4	SGSXTN	4E15.8	1

Section	Variable	Definition
1	ISXTB	bias control flag
		= 0 use prestored σ's to compute the biases
		= 1 use input σ's to compute the biases
		= 2 use input biases
	ISXTN	noise control flag
		= 0 use prestored σ's to compute the noise values
		= 1 use input σ's to compute the noise values
2	This section is read only if ISXTB = 1	
	SGSXTB	σ's for computing sextant bias values, rad
3	This section is read only if ISXTB = 2	
	SXTBIA	sextant bias values, rad
4	This section is read only if ISXTN = 1	
	SGSXTN	σ's for computing sextant noise values, rad

Block G Input - SCT Lunar Landmark Tracking

This block inputs the lunar landmarks used for CSM SCT tracking. Up to 25 lunar landmarks may be input. The prestored landmarks are those given in reference 10.

This block is included only if IBLOCKG = 1.

Section	Variables	Format	Cards
1	NLM	I15	1
2	XLAT, XLON, XALT	3F10.0	NLM

Section	Variable	Definition
1	NLM	the number of lunar landmarks to be input to the program
2	This section is read once for each landmark input	
	XLAT	latitude of landmark, deg
	XLON	longitude of landmark, deg
	XALT	altitude of landmark above mean lunar radius, ft

Block H Input - Lunar Ascent and Descent Data

This block provides input needed to perform powered descent, ascent from the lunar surface, and ascents that follow aborts from powered descent. The reference landing site which is used to target powered descent and to form the actual landing site for ascents from the surface is defined in section 1. Insertion targets for ascents from the surface are input in section 2, while ascents that follow descent aborts use the K constants in sections 3 and 4 to compute the desired insertion conditions.

If IBLOCKH = 0, no data is included in this section.

Section	Variables	Format	Cards
0	JHFLAG(I), I = 1, 4, LSA, LSE	6I5	1
1	LONLS, LATLS, ALTLS	3F10.0	1
2	HA, HP, TRUE, YDD, YD, $\Delta\phi$	6F10.0	1
3	K_o(DPS), K_1(DPS), K_2(DPS), K_3(DPS)	4E15.8	1
4	K_o(APS), K_1(APS), K_2(APS), K_3(APS)	4E15.8	1
5	COVLSA	3E15.8	3
6	DXLSA	3F10.0	1
7	COVLSE	3E15.8	3
8	DXLSA	3F10.0	1

Section	Variable	Definition
0	JHFLAG	flags that designate whether sections 1 through 4 of this block are to be input
		= 0 do not read in this section
		= 1 read in this section
	LSA	actual landing site designation flag
		= 0 actual landing site is computed from performing descent
		= 1 actual landing site equals the reference landing site
		= 2 the actual landing site equals the reference landing site plus a random sampling of the covariance matrix COVLSA
		= 3 the actual landing site equals the reference landing site plus an input dispersion
	LSE	estimated landing site designation flag
		= 0 the estimated landing site is computed from performing descent
		= 1 the estimated landing site equals the actual landing site
		= 2 the estimated landing site equals the actual landing site plus a random sampling of the covariance matrix COVLSE
		= 3 the estimated landing site equals the actual landing site plus an input dispersion

Section	Variable	Definition
1	This section is included only if JHFLAG(1) = 1	
	LONLS	selenographic longitude of the reference landing site, deg
	LATLS	selenographic latitude of the reference landing site, deg
	ALTLS	altitude of the reference landing site above mean lunar radius, n. mi.
2	This section is included only if JHFLAG(2) = 1	
	HA	desired apogee height of ascent insertion orbit, n. mi.
	HP	desired perigee height of ascent insertion orbit, n. mi.
	TRUE	desired true anomaly at insertion, deg
	YDD	desired out-of-plane distance at insertion, ft
	YD	desired out-of-plane velocity at insertion, fps
	$\Delta\phi$	desired phase angle at insertion in deg; used if the lift-off time is to be calculated by the program
3	This section is included only if JHFLAG(3) = 1	
	K_o, K_1, K_2, K_3	constants used to calculate the variable insertion targets used for DPS powered ascents following abort from powered descents

Section	Variable	Definition
4	This section is included only if JHFLAG(4) = 1	
	K_o, K_1, K_2, K_3	APS constants corresponding to the DPS constants of section 3
5	This section is included only if LSA = 2	
	COVLSA	3-by-3 covariance matrix in feet in UVW coordinates for calculation of the actual landing site from the reference landing site
6	This section is included only if LSA = 3	
	DXLSA	dispersions in feet in selenographic coordinates added to the reference landing site to form the actual landing site
7	This section is included only if LSE = 2	
	COVLSE	3-by-3 covariance matrix in feet in UVW coordinates for calculation of the estimated landing site from the actual landing site
8	This section is included only if LSE = 3	
	DXLSE	dispersion in feet in selenographic coordinates added to the actual landing site to form the estimated landing site

Block EVENT Input - Basic EVENT Input

Block EVENT initiates each event package in the desired mission profile. The input in this block routes the program to one of the blocks LEC1, LEC2, LEC3, or LEC4 where the specific input for the requested event is read. Upon completion of the reading of the specific LEC block, the program returns to this block to read the next event package. The branching to the LEC blocks and the return to block EVENT is continued until an LEC = 5 is encountered, which signifies the end of the input to the program.

When KTHR = 1, the program reads block NEWTHR before it branches to the LEC blocks.

Section	Variables	Format	Cards
1	Comment card	10A6	1
2	LEC, LEN, ICOM, IVEH, IENG, ITEV, ISAM, IPRINT, KEST, KTHR, IEX, ITDV, IPN, IDISPLY KTARG	15I5	1
3	JSFLAG	8I5	1
4	JDFLAG	10I5	1

Section	Variable	Definition
1		a comment card which contains any information the user wishes to be displayed for this event
2	LEC, LEN	these flags specify the event to be done
		LEC = 1 the event is a maneuver
		LEN = 0 target ΔV maneuver
		= 1 external ΔV maneuver
		= 2 stable orbit initiation maneuver
		= 3 stable orbit midcourse maneuver
		= 4 stable orbit rendezvous maneuver

Section	Variable		Definition
		= 5	CSI maneuver
		= 6	CDH maneuver
		= 7	TPI maneuver
		= 8	TPM maneuver
		= 9	direct transfer to input target
		= 10	Direct intercept maneuver
		= 11	Braking
		= 12	DOI maneuver
		= 13	lunar descent
		= 14	lunar ascent
		= 15	plane change maneuver
		= 16	TPI search
		= 17	NCC maneuver
		= 18	NSR maneuver
		= 19	staging maneuver
		= 20	lunar descent with abort followed by powered ascent
		= 21	CSM lunar orbit plane change
		= 22	NC1 - NSR sequence
		= 23	NC1 - NH - NSR sequence
		= 24	NH - NC1 - NSR sequence
		= 25	NH - NSR sequence
		= 26	LM insertion corrective (or tweak) maneuver
		LEC = 2	the event is an alinement

Section	Variable		Definition
		LEN = 0	realinement
		= 1	local vertical alinement
		= 2	LM nominal alinement
		= 3	line-of-sight alinement
		= 4	preferred alinement
		= 5	landing site alinement
		= 6	align AGS platform to the present PGNCS platform
		LEC = 3	the event is an update event
		LEN = 0	discontinue monitoring the computer designated by ICOM
		= 1	vector transfer from one computer to another
		= 2	onboard tracking update (sampling from a covariance matrix)
		= 3	MSFN update (sampling from a 12-by-12 covariance matrix)
		= 4	MSFN update (sampling a 6-by-6 covariance matrix)
		LEC = 4	the event is an update event
		LEN = 0	rendezvous radar data display (no actual updates are made)
		= 1	rendezvous radar update
		= 2	sextant vehicle to vehicle update
		= 3	lunar landmark tracking
		LEC = 5	end of case (this is the last data card)

Section	Variable	Definition
	ICOM	specifies the computer doing the event
		= 1 CMC
		= 2 LM PGNCS
		= 3 LM AGS
		= 4 RTCC
		= 5 actual state (usable only in vector replacements)
	IVEH	specifies the vehicle doing the event
		= 1 CSM
		= 2 LM
	IENG	engine used for the maneuver
		= 1 RCS, = 2 SPS — for CSM
		= 1 RCS, = 2 DPS, = 3 APS — for LM
	ITEV	event time source (for ITEV > 0, see the discussion on event times at the end of this section)
		= 0 the time is input
		= 1 TEVENT = TNEXT
		= 2 TEVENT = TNEXT + TEVENT
		= 3 the time is program computed
	ISAM	reference point designation
		= 0 this is not a reference point
		= 1 compute reference point data for the estimated state only
		= 2 compute reference point data for both the estimated and actual states

Section	Variable	Definition
		= 3 compute the maneuver targeting solutions and differences requested by JSFLAG and JDFLAG
		= 4 compute all maneuver targeting solutions and differences
		= 5 this is a nonmaneuver reference point
	IPRINT	print control flag
		= 0 minimum output
		= 1 full output print
		= 2 debug and ohter special print
	KEST	estimated state propagation flag
		= 0 use onboard coasting integrator
		= 1 use the AEG
	KTHR	thrust model control flag
		= 0 continue with present thrust model
		= 1 read in new thrust model through block NEWTHR
	IEX	maneuver execution control
		= 0 execute the maneuver trimming residuals to zero
		= 1 execute the maneuver with trim
		= 2 execute the maneuver without trimming any residuals
		= 3 execute the maneuver without trimming any residuals and introduce random pointing errors into the state

Section	Variable	Definition
		= 4 do not execute the maneuver
		= 5 execute the maneuver impulsively
	ITDV	monitored computer update
		= 0 in addition to performing the maneuver with the designated primary computer, update the states of other monitored computers by means of thrust monitoring or target ΔV procedures
		= 1 do not effect updates on the non-primary monitored computers
	IPN	out-of-plane velocity nulling flag
		= 0 do not null the out-of-plane velocity
		= K remove the out-of-plane velocity based on the estimated states of computer K
	IDISPLY	display flag
		= 0 no display given
		= 1 display ΔΔh data
		= 2 display closest approach data
	KTARG	DKI sequence flag (used only in DKI events)
		= 0 first maneuver in a DKI sequence with maneuver times input
		= 1 first maneuver in a DKI sequence with maneuver times computed from a counter line
		= 2 maneuver after the first maneuver in a DKI sequence; retarget maneuver ΔV
		= 3 maneuver after the first maneuver in a DKI sequence; use previously computed ΔV values

Section	Variable	Definition
	Sections 3 and 4 are included only if ISAM = 3	
3	JSFLAG	requested solution flags. The program can compute eight different solutions for each maneuver, each designated by the corresponding JSFLAG. The possible solutions are as follows. JSFLAG(1) - CMC JSFLAG(2) - PGNCS JSFLAG(3) - AGS JSFLAG(4) - RTCC JSFLAG(5) - ACT/CMC JSFLAG(6) - ACT/PGNCS JSFLAG(7) - ACT/AGS JSFLAG(8) - ACT/ACT The values of the JSFLAG's are as follows. = 0 do not compute the corresponding solution = 1 compute the solution = 2 compute the solution based on the ICOM computer time (used only for CDH maneuvers)

Section	Variable	Definition
4	JDFLAG	This flag designates which differences in maneuver targeting are to be displayed. The possible differences are as follows.

JDFLAG (1) - CMC minus ACT/CMC

JDFLAG (2) - PGNCS minus ACT/PGNCS

JDFLAG (3) - AGS minus ACT/AGS

JDFLAG (4) - RTCC minus ACT/ACT

targeting errors

JDFLAG (5) - CMC minus PGNCS

JDFLAG (6) - CMC minus AGS

JDFLAG (7) - CMC minus RTCC

JDFLAG (8) - PGNCS minus AGS

JDFLAG (9) - PGNCS minus RTCC

JDFLAG (10) - AGS minus RTCC

targeting differences

The values of JDFLAG are as follows.

= 0 do not display the given difference

= 1 display the difference

On maneuvers with fixed times solutions, 5 through 8 above become identical and only solution 8 should be requested in setting JSFLAG. Differences involving solutions 5 through 7 can still be requested in setting JDFLAG because the program will substitute solution 8 in their place.

EVENT TIME SOURCES

ITEV = 1 (TNEXT Table)

When ITEV = 1 the time of the requested event is taken as TNEXT where TNEXT has been calculated by a previously executed maneuver event. A given TNEXT will continue in effect until it is replaced by a new one. However, it should be remembered that not all maneuvers define TNEXT. The table below indicates the maneuvers that define TNEXT and how it is defined.

LEN	Maneuver	TNEXT definition
7,12	maneuvers with IEX = 4	time of unexecuted maneuver
2	SOI	time of SOR
5	CSI	time of CDH
6	CDH	time of TPI
7	TPI	time of TPF
12	DOI	time of DOI plus 180°
13	descent	time of touchdown
14	ascent	insertion plus 50 minutes
17	NCC	time of NSR
20	descent abort	insertion plus 50 minutes
21	CSM plane change	time of passage over landing site
22	NC1, NSR sequence	time of NSR
23	NC1, NH, NSR sequence	time of NH
24	NH, NC1, NSR sequence	time of NC1
25	NH, NSR sequence	time of NSR

ITEV = 3 (Program Computed Times)

When ITEV = 3, the maneuver time is computed based on logic particular to the event in question. The table below gives the special maneuver time options available.

LEN	Event	Definition
1	external ΔV	program computed external ΔV maneuver
5	CSI	CSI at an apsis (input TCSI as a threshold time)
14	ascent	lift-off time computed from desired phase desired phase angle at insertion

Block NEWTHR Input - New Thrust Profile

The reading of this block changes the thrust profile for the engine specified by the values of IVEH and IENG. On each subsequent event in the profile the program will continue to use the new thrust profile for the given engine until this block is again read for that engine.

This block is read only when KTHR = 1.

Section	Variable	Format	Cards
0	JEFLAG	12I5	1
1	IME, ITHRC, ITHROT	3I5	1
2	ITHR(I), I = 1, 10	10I5	1
3	THR(I), I = 1, 10	5F10.0	2
4	SPI(I), I = 1, 10	5F10.0	2
5	PHT(I), I = 1, 10	5F10.0	2
6	THRA(I), I = 1, 10	5F10.0	2
7	SPIA(I), I = 1, 10	5F10.0	2
8	PTHRE(I), I = 1, 10	5F10.0	2
9	PSPIE(I), I = 1, 10	5F10.0	2
10	SIGTHR(I), I = 1, 10	5F10.0	2
11	SIGSPI(I), I = 1, 10	5F10.0	2
12	ENO, C	2FI0.0	1

Section	Variable	Definition
0	JEFLAG	engine data control flags that correspond to sections 1 through 12 of this block and that designate whether the corresponding section is to be read = 0 continue with present values for this section = 1 read in new values for this section
1	IME	phase number of the main engine phase
	ITHRC	main engine phase thrust control = 0 main engine phase thrust is constant = 1 main engine phase thrust varies linearly
	ITHROT	DPS throttling flag = 0 normal DPS operation = 1 manually throttled maneuver overriding short burn logic
2	ITHR	designates how the actual thrust and SPI are determined for each phase of each engine = 0 actual thrust and SPI equal nominal plus percentage errors = 1 actual thrust and SPI computed from nominal and error σ's = 2 actual thrust and SPI values are input
3	THR	nominal thrust levels for each phase, lb
4	SPI	nominal specific impulse levels for each phase, sec

Section	Variable	Definition
5	PHT	phase times for each phase, sec
6	THRA	actual thrust levels for each phase, lb
7	SPIA	actual specific impulse values for each phase, sec
8	PTHRE	percentage errors in the thrust for each phase
9	PSPIE	percentage errors in the specific impulse for each phase
10	SIGTHR	error σ's for computation of the actual thrust values for each phase, lb
11	SIGSPI	error σ's for computation of the actual SPI values for each phase, sec
12	ENO	number of RCS thrusters to be used
	C	steering parameter

Block LEC1 Input - Maneuver Event

Block LEC1 provides the input needed to perform a specific maneuver in the mission profile. Only one section of this block will be read. When LEN equals zero, the block is not read.

For each maneuver event, the ignition time and impulsive ΔV computed for the primary computer are saved in the program until a subsequent maneuver replaces them. The stored time and ΔV are applied in target ΔV maneuvers (LEN = 0) and program-computed external ΔV maneuvers (LEN = 1, ITEV = 2). Program-computed external ΔV maneuvers are maneuvers computed but not executed in one computer and then executed in another computer.

The DKI sequence has the option to use what is called a counter line to establish its maneuver times. The counter line may be established in three ways: at the threshold time THCL, at the first apsis after the threshold time THCL, or at a delta time DTCL off the first apsis after the threshold time THCL. When using the counter line option, maneuver times are designated by specification of the number of the counter lines crossing at which the maneuver is to occur.

This block is read when LEC = 1. The only section of the block read is the section that corresponds to the value of LEN.

Section	Variables	Format	Cards
1	TEVENT, DVX, DVY, DVZ	4F10.0	1
2	TSOI, ωt, $\Delta\phi$	3F10.0	1
3	δt	F10.0	1
4	ωt	F10.0	1
5	TCSI, TTPI, NCDH, EL	4F10.0	1
6a	TCDH	F10.0	1
6b	TTPI, EL, TBIAS	3F10.0	1
7	TTPI, EL, ωt, TDELT	4F10.0	1
8	δt	F10.0	1
9	TEVENT, δt, XTARG, YTARG, ZTARG	5F10.0	1
10	TEVENT, δt	2F10.0	1
11	Undefined at this time		
12	TDOI	F10.0	1
13	TEVENT	F10.0	1
14	TLO, WHTTLO	2F10.0	1
15	TPC	F10.0	1
16	Undefined at this time		
17a	IROUTE	I5	1
17b	TNCC, TNSR, TSHIFT(NCC), TSHINC(NCC) TSHIFT(NSR), TSHINC(NSR), TSHIFT(TPI) TSHINC(TPI)	8F10.0	1
17c	DH, DHMIN, DHMAX, DHINC, DPH, DPHMIN, DPHMAX, DPHINC	8F10.0	1
18a	TNSR	F10.0	1
18b	TSHIFT, TTPI, EL	3F10.0	1
19	TEVENT, WAFTER, AREA, DVX, DVY, DVZ	6F10.0	1

Section	Variables	Format	Cards
20	TEVENT, TABORT, TSTAGE, WSTAGE, WAFTER RDOT	6F10.0	1
21	TEVENT, TLO	2F10.0	1
22a	DHD, THCL, TTPI, EL, DTCL	5F10.0	1
22b	N1, N2, N3	3I5	1
22c	TN1, TN2, TN3	3F10.0	1
23a	DHD, THCL, TTPI, EL, DTCL	5F10.0	1
23b	N1, N2, N3	3I5	1
23c	TN1, TN2, TN3	3F10.0	1
24a	DHD, THCL, TTPI, EL, DTCL	5F10.0	1
24b	N1, N2, N3	3I5	1
24c	TN1, TN2, TN3	3F10.0	1
25a	DHD, THCL, TTPI, EL, DTCL	5F10.0	1
25b	N1, N2, N3	3I5	1
25c	TN1, TN2, TN3	3F10.0	1
26	TEVENT, K, TTPI, NCDH, EL, DHD	6F10.0	1

Section	Variable	Definition
1	This section is read only if ITEV = 0	
	TEVENT	time of the maneuver in sec
	DVX	X component of $\Delta V(LV)$, fps
	DVY	Y component of $\Delta V(LV)$, fps
	DVZ	Z component of $\Delta V(LV)$, fps
2	TSOI	time of the maneuver, sec
	ωt	passive vehicle travel angle between SOI and SOR maneuvers, deg
	$\Delta\phi$	desired phase angle at SOR, deg, or desired displacement distance at SOR, ft
3	δt	delta time from SOI to the midcourse maneuver, min
4	ωt	passive vehicle travel angle between SOR and the time of orbit intersection measured, deg
5	TCSI	time of CSI, sec
	TTPI	time of TPI, sec
	NCDH	apsis after CSI where CDH is to occur. If NCDH is input negative CDH occurs NCDH multiples of 180° from CSI
	EL	desired elevation angle at TPI, deg
6a	This section is included only if ITEV = 0	
	TCDH	time of CDH, sec
6b	TTPI	time of TPI, sec
	EL	desired elevation angle at TPI, deg
	TBIAS	CDH time bias, sec

Section	Variable	Definition
7	TTPI	TPI threshold time, sec
	EL	desired elevation angle, deg; if EL = 0 then the maneuver is done on the input threshold time
	ωt	passive vehicle travel angle between TPI and TPF, deg (used by all computers except AGS)
	TDELT	time from TPI to TPF, sec (for AGS)
8	δt	delta time from TPI to TPM, min
9	TEVENT	time of transfer maneuver, sec
	δt	time from transfer to intercept, min
	XTARG	X component of target point, ft
	YTARG	Y component of target point, ft
	ZTARG	Z component of target point, ft
10	TEVENT	time of transfer maneuver, sec
	δt	time from transfer to intercept, min
12	TDOI	threshold time of DOI maneuver, sec
13	This section is included only if ITEV = 0	
	TEVENT	time of powered descent initiation, sec
14	TLO	lift-off time, sec
	WHTTLO	liftoff weight of LM, lb
15	This section is included only if ITEV = 0	
	TPC	time of plane change maneuver, sec
17a	IROUTE	NCC-NSR processor route = 0 vary NSR time to hold TPI time (fast computation route) = 1 vary NSR time to hold TPI time (slow computation route)

Section	Variable	Definition
		= 2 hold NSR time and vary TPI time
		= 3 vary NCC and NSR times, ignore TPI time
17b	TNCC	nominal NCC time
	TNSR	nominal NSR time
	TSHIFT	time the given maneuver is allowed to slip
	TSHINC	increment the given maneuver is allowed to slip. (Each TSHINC must not be less than one-fifth the corresponding TSHIFT value.)
17c	DH	nominal Δh, n. mi.
	DHMIN	minimum Δh, n. mi.
	DHMAX	maximum Δh, n. mi.
	DHINC	Δh increment, n. mi.
	DPH	nominal $\Delta\phi$, deg
	DPHMIN	minimum $\Delta\phi$, deg
	DPHMAX	maximum $\Delta\phi$, deg
	DPHINC	$\Delta\phi$ increment, deg
18a	This section is included only if ITEV = 0	
	TNSR	time of NSR, sec
18b	TSHIFT	time that NSR is allowed to shift to obtain the desired elevation angle at TPI, sec
	TTPI	time of TPI, sec (not needed if TSHIFT = 0)
	EL	desired elevation angle at TPI, deg (not needed if TSHIFT = 0)
19	TEVENT	time of staging, sec
	WAFTER	weight of vehicle after staging, lb
	AREA	area of LM after descent staging, ft^2

Section	Variable	Definition
	DVX	X component of staging maneuver $\Delta V(LV)$, fps
	DVY	Y component of staging maneuver $\Delta V(LV)$, fps
	DVZ	Z component of staging maneuver $\Delta V(LV)$, fps
20	TEVENT	threshold time for powered descent in sec
	TABORT	time from powered descent initiation at which abort occurs, sec
	TSTAGE	maximum time from powered descent initiation at which staging is to occur, sec
	WSTAGE	weight of vehicle at which staging is to occur, lb
	WAFTER	weight of vehicle after staging, lb
	RDOT	desired radial rate at insertion
21	TEVENT	threshold time for CSM plane-change maneuver
	TLO	desired lift-off time of LM, sec
22a	This section is included only if KTARG < 2	
	DHD	desired Δh at NSR, n. mi.
	THCL	threshold time for establishing the DKI counter line, sec
	TTPI	desired TPI time, sec
	EL	desired elevation angle at TPI, deg
	DTCL	time the counter line is to be moved off the first apsis crossing after THCL if DTCL $\geq$ 5000 sec; establish counter line at THCL
22b	This card is included only if KTARG = 1	
	N1	number of the counter line crossing after the counter line establishment at which the first maneuver in the DKI sequence is to occur. (N1 $\geq$ 0 where the zero crossing designates the crossing at which the counter line was established)

Section	Variable	Definition
	N2	the number of counter line crossings after the first maneuver at which the second maneuver will occur
	N3	the number of counter line crossings after the second maneuver at which the third maneuver will occur
22c	This section is included only if KTARG = 0	
	TN1	time of first maneuver of a DKI sequence in seconds
	TN2	time of second maneuver of a DKI sequence in seconds
	TN3	time of third maneuver of a DKI sequence in seconds
23	See section 22	
24	See section 22	
25	See section 22	
26	TEVENT	time of maneuver, sec
	K	weighting factor used to compute the maneuver based on the Δh error
	TTPI	time of TPI, sec
	NCDH	see section 5
	EL	desired elevation angle at TPI, deg
	DHD	desired Δh at CDH, n. mi.

Block LEC2 Input - Alinement Event

AGAST can compute the REFSMMAT for several different forms of alinement. REFSMMAT is the transformation matrix from the basic reference coordinates to the IMU assuming a perfect alinement. Platform misalinement and drift errors are introduced in the programs where they are to be used. The realinement option does not change the REFSMMAT, but a new misalinement is computed and the drift rates built up because the original alinement is removed and begins building up again from the realinement time.

The following platform coordinate systems are used in various parts of the AGAST program.

1. The CSM IMU nominal alinement or local vertical (LV) coordinates

   X-axis - in the direction of motion perpendicular to the radius vector

   Y-axis - opposite the direction of the angular momentum vector

   Z-axis - downward along the radius vector

2. The LM IMU nominal alinement coordinates

   X-axis - outward along the radius vector

   Y-axis - downward along the angular momentum vector

   Z-axis - in the direction of motion perpendicular to the radius vector

3. Line-of-sight (LOS) coordinates

   X-axis - along the line of sight to the other spacecraft

   Y-axis - in the direction of the vector formed by crossing the radius vector of the other vehicle into the spacecraft radius vector

   Z-axis - along $(X \times Y)$

4. Preferred alignment coordinates

   X-axis - along the thrust vector

   Y-axis - along the vector formed by crossing the thrust vector into the radius vector

   Z-axis - along (X × Y)

5. UVW coordinates

   U-axis - upward along the radius vector

   V-axis - in the direction of motion perpendicular to the radius vector

   W-axis - upward along the angular momentum vector

6. Landing site alignment

   X-axis - from center of moon through the landing site

   Y-axis - along (Z × X)

   Z-axis - along the vector formed by crossing the CSM angular momentum vector into the X axis

This block is read only when LEC = 2.

Section	Variables	Format	Cards
1	TEVENT	F10.0	1

Section	Variable	Definition
1	TEVENT	time of the alignment, sec

Block LEC3 Input - Vector Replacement Event

The purpose of this block is to update a computer's estimated state with a vector replacement. The update is accomplished by sampling a covariance matrix or by setting the estimate equal to an estimate of another computer or vehicle. ICR and IVR define which computer and vehicle the estimate is taken from and ICOM and IVEH (block EVENT) define the computer and vehicle of the state that is to be replaced.

This block is read only if LEC = 3.

Section	Variables	Format	Cards
1	TEVENT	F10.0	1
2	ICR, IVR	2I5	1
3	IROT, IUPDATE(CMC), IUPDATE(PGNCS), IUPDATE(AGS), IUPDATE(RTCC)	5I5	1
4	COV_{OT}	MATRIX	6
5	COV_{MSFN}	MATRIX	6 or 18

Change 1, May 20, 1969
Change 2, June 23, 1969

Section	Variable	Definition
1	TEVENT	time of the event, sec
2	This section is read only if LEN = 1	
	ICR	source from which the vector is to be taken = 1 CMC = 2 LM PGNCS = 3 LM AGS = 4 RTCC = 5 Actual
	IVR	vehicle which is to be taken = 1 CSM = 2 LM
3	This section is read only if LEN $\neq$ 1	
	IROT	designates coordinate system of the update matrix = 0 Apollo local vertical = 1 UVW local vertical
	IUPDATE	automatic vector replacement option following MSFN or tracking matrix updates = 0 do not transfer vectors to this computer (IUPDATE (ICOM) is left to zero unless a 6-by-6 matrix is being used and the IUPDATE = 3 option is desired) = 1 update the CSM state of this computer using the CSM state of a 12-by-12 matrix sampling or with the state obtained by a 6-by-6 matrix sampling = 2 update the LM state of this computer using the LM state of a 12-by-12 matrix sampling or with the state obtained by a 6-by-6 matrix sampling = 3 update both the CSM and LM states of this computer (if the update is from a 6-by-6 matrix, the states are set equal)

Section	Variable	Definition
4	This section is read only if LEN = 2	
	COV_{OT}	6-by-6 covariance matrix for onboard rendezvous radar or sextant tracking measured in ft and fps
5	This section is read only if LEN $\geq$ 3	
	COV_{MSFN}	covariance matrix representing MSFN uncertainties; when LEN = 3, the matrix is 12-by-12 and updates both vehicles; when LEN = 4, the matrix is 6-by-6 and updates only the state designated by IVEH

Block LEC4 Input - Update Event

This block provides the data necessary to update an estimated state by simulation of one of the onboard tracking systems modeled in AGAST. IVRR is the estimated state which is to be updated as opposed to IVEH (block EVENT) which indicates the vehicle doing the tracking.

The W-matrix is initialized by setting the diagonal values equal to the WDIAG values and by setting the nondiagonal terms to zero. The WDIAG values are not affected by the propagation of the W-matrix.

The initialization of the W-matrix and the WDIAG values used are dictated by the value of IWMATRX. When IWMATRX = 1, a new set of WDIAG values are read in to initialize the W-matrix. When IWMATRX = 2, the WDIAG values used previously are again used for the initialization. Using IWMATRX = 2 on the first initialization causes the program to use the prestored WDIAG values.

The block is read only if LEC = 4.

Section	Variables	Format	Cards
1	IVRR, IWMATRX, IMARK, IANGLE, IGIM, ISTART, ISTOP, NCODE	8I5	1
2	TSTART, TSTOP, DTMARK, DTSTART, DSTOP, DTRACK, ANGLMT	7F10.0	1
3	WDIAG	3E15.8	3
4	LCØDE(I), I = 1, NLM	16I5	1 or 2

Section	Variable	Definition
1	IVRR	estimated state to be updated by the tracking
		= 1 CSM
		= 2 LM
	IWMATRX	W matrix control flag
		= 0 continue with present W matrix
		= 1 initialize with new WDIAG values
		= 2 initialize W matrix with current WDIAG values
	IMARK	mark interval control
		= 0 use prestored mark interval time (60 sec)
		= 1 input the time between marks
	IANGLE	tracking data measurement control flag
		= 0 use both range and angle data
		= 1 use range data only
		= 2 use angle data only
	IGIM	tracking attitude control flag
		= 0 hold a line-of-sight attitude within the angle limit
		= 1 do not hold a line-of-sight attitude
	ISTART	start time control flag
		= 0 use input start time
		= 1 TSTART = TLAST + DSTART

Section	Variable	Definition
	ISTOP	tracking interval stop time control
		= 0 use input stop time
		= 1 STOP = TSTART + DTRACK
		= 2 TSTOP = TNEXT - DSTOP
	NCODE	lunar landmark control flag (used only with LEN = 3)
		= 0 continue use of present set of landmarks
		= 1 input a new set of landmark flags
2	TSTART	tracking start time, sec
	TSTOP	tracking interval stop time, sec
	DTMARK	time interval between marks, sec (input A value only when IMARK = 1)
	DSTART	time from TLAST to start of tracking, sec
	DSTOP	time from end of tracking to TNEXT, sec
	DTRACK	length of tracking interval, sec
	ANGLMT	angle limit within which the line-of-sight attitude must be held during tracking, deg
3	This section is read only if IWMATRX = 1	
	WDIAG	W=matrix diagonal values used to reinitialize the W-matrix measured, ft, fps, and rad
4	LCØDE	flags that correspond to the 25 lunar landmarks and that designate which ones are to be used for tracking on this event
		= 0 do not use the given landmark
		= 1 use the given landmark

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